Summary

In the Introduction three known factors were described that drive overt selection behavior. These are stimulus- and goal-driven influences, and a recently identified factor associated with selection history. All appear to have unique characteristics and a distinct role in determining which parts of the visual environment are selected by attention and gaze. First, stimulus-driven influences have a strong impact on overt selection, but one that is merely short-lived. Unlike many prominent theories suggest (e.g., Itti et al., 1998), salience does not affect oculomotor behavior continuously. The only way salience can affect overt selection late in time, i.e., after a first oculomotor response has been made, is when salience levels of stimuli are abruptly changed. Siebold and Donk (2014) provided the first clues for salience-driven capture for ‘second’ eye movements. In a search task involving two saccadic eye movements, the second movement was captured by a salient singleton if it had changed during the first movement. Since, according to Brockmole and Henderson (2005), a change in a scene could also lead to capture due to a mismatch between the visual scene and memory representations of the scene, more evidence was required to affirm that the observations of Siebold and Donk (2014) were truly driven by salience. Chapter 2 described a series of experiments in which participants were asked to search for a target in a two-eye-movements task closely modeled after Siebold and Donk (2014). The results showed that a change in a search scene only induced oculomotor capture when the change involved a salience increase. This result indicated that salience must have been responsible for the late capture effects in Siebold and Donk (2014), not a memory representation mismatch.

Continuing on the temporal characteristics of the influence of salience, Chapter 3 explored the idea that salience might be a physical property with which the system segregates objects from the background, rather than a property that leads to a continuous prioritization. It was hypothesized that objects that are highly salient are detected faster by the system than objects that are less salient. Consequently, a faster detection of particular objects could account for an initial bias to select particular objects. Moreover, salience effects are transient because the selection bias is removed by obtaining knowledge regarding the presence of multiple objects in a scene. This line of reasoning was discussed and examined in Chapter 3. In a set of search task experiments,
the onset asynchrony of singletons (target and distractor) relative to the background elements was varied. At the moment when the singletons and background elements were both present in the display, the background elements elicited a salience difference between the singletons. The results showed that indeed salience-driven effects abruptly disappear as a consequence of the prior availability of object location information. A salience difference between the singletons, as induced by the background elements, only had a prominent influence on oculomotor selection performance when the onset of the singletons and background elements was simultaneous. Additionally, the results showed the effects of salience to reduce regardless of whether the singletons or the background elements appeared first, so regardless whether information concerning the target was present early or late. This observation indicates that salience and goal-driven mechanisms are independent. Goal-driven mechanisms do not seem responsible for down regulating the strength of salience effects. Together, the findings confirm the idea that salience effects are caused by variations in the speed with which objects can be detected and that salience no longer affect oculomotor selection once multiple objects in a scene have been detected.

Besides oculomotor capture, another eye movement phenomenon that is typically considered stimulus-driven is the global effect. However, recent studies using search arrays consisting of relatively complex real-world objects have demonstrated that saccades can land in between objects also when they are initiated after the initial oculomotor response (Zelinsky et al., 1997). Since it was unknown whether these findings could be compared with the traditional global effect, involving simple objects and saccades that are initiated early in time, Chapter 4 described a set of experiments that employed a two-eye-movement paradigm with simple target and distractor objects. The early availability of different types of information was manipulated, as the target and distractor could either (i) appear immediately, (ii) appear only during the first eye movement, or (iii) appear immediately as two anonymous points in space, only obtaining the target and distractor identities during the first eye movement. The results showed that the absence of identity information could induce a global effect, even when the spatial information regarding the potential target and distractor positions were given, which is in line with the findings of Zelinsky et al. (1997).
Finally, another influence that relates to the goals of the observer, but one that appears to operate in an automatic involuntary manner, is working memory content. Working memory can therefore be thought to belong to the selection history class, together with reward, contextual cueing, and feature priming. However, the recent studies that observed an influence of working memory content on overt selection have not irrefutably confirmed whether the influence of working memory content can be seen as distinct from feature-based priming. Chapter 5 elaborated on empirical work in which a color memory task was performed together with a search task in which the items consisted of task-irrelevant colors. In two separate experiments, memory content was either probed before or after the search task and so working memory content could either be dropped before search, or still had to be held active in working memory during search. In both designs, the results indicated that the memory color influenced oculomotor selection during search. When the color of one of the search items matched the memory color, the item was more likely to be gazed at. However, as this influence turned out stronger when memory content was still actively maintained, the results suggested that working memory content does have a unique influence on oculomotor selection, distinct from feature-based priming.

Conclusion

This thesis proposed a descriptive model aiming to account for and integrate the known factors that drive overt selection. The empirical work discussed in Chapters 2 to 5 supports it. The model assumes that visual salience, as a physical property, is used by the visual system to segregate objects from the background. Salience simply provides the information about where to find objects, not necessarily which objects in the scene should be prioritized over others. Salience is therefore not represented as relative activity differences in an internal topographical representation of the visual environment, e.g. a salience map. Instead, salience enables the generation of a 'flat landscape' representation that yields the spatial positions of objects. Salience therefore only has a prominent influence on selection behavior when object locations have yet to be determined. Accordingly, immediately after the onset of a new visual scene, the influence of salience on selection behavior is strongest. A
selection bias arises when a highly salient object is detected earlier than objects that are less salient. For a brief period of time, the system may have detected a single object only, presumably the object of the highest salience level, leaving the system no other option but to select this region in space first. Later in time, when a more elaborate representation of the positions of objects in the visual scene is established, there will be no preference anymore to select a highly salient object over other objects that are less salient. Likewise, selection history could have a similar effect on selection behavior. The speed with which the system segregates an object from the background, or simply the speed with which an object can be spotted in a scene, could for instance be facilitated by having selected the same object in the past. This explains why and how an early selection bias could be installed by mechanisms such as feature-based priming. Accordingly, the influence of selection history is strongest immediately after the onset of a visual presentation, when the locations of objects in a scene still have to be processed. This prediction is confirmed by the observations in Chapter 5. Both the influence of feature-based priming on oculomotor selection, as well as the influence of active working memory content, is short-lived. The earliest eye movements were affected by selection history most profoundly.

For overt selection behavior beyond the first eye movement, salience-driven effects, or effects associated with selection history, should be absent, since by that time the system should already have identified where to find the objects in the scene. The only exception would be when there is a sudden appearance of novel objects. Indeed, the studies discussed in Chapter 2 confirm that a large and abrupt increase of a local salience level can reinstate the influence of salience on overt selection. The same work additionally demonstrated that the decrease of a local salience level cannot lead to a reinstatement of salience effects, despite the fact that the salience decrease led to a profound difference between the relative salience levels of the distinct object locations in the scene. This suggests that the visual system does not represent and maintain relative salience differences between objects. The system only appears to be interested in abrupt local salience increases, since these are presumably indicative for the onset of new objects. The work discussed in Chapter 3 also supports the idea that relative differences in salience are not a continuous driving force behind overt selection. Once the locations of prominent objects in the scene are known, the strength in effects driven by salience is abruptly
reduced. Since this reduction was the same regardless of the presence or the absence of information about the location of the target, the results additionally implied that the role of salience and the generation of an object-ground representation are unrelated to goal-driven mechanisms. This is congruent with the proposed model.

Only once the visual system has generated a representation of the scene containing multiple objects, goal-driven signals may gain control. Goal-driven mechanisms might operate directly based on an explicit target representation (e.g., Zelinsky et al., 1997), or more implicitly through a semantic or episodic understanding of the context of the scene (e.g., Henderson, 2009). In any case, at the stage at which the locations of the objects in a scene have been processed, stimulus-driven effects or the effects related to selection history will not influence overt selection anymore. The only observation that seemed to challenge this assumption is the work of Zelinsky et al. (1997). They predicted and found eye movement behavior beyond the first response that appeared to yield a global effect, a phenomenon typically considered stimulus-driven. However, Chapter 4 confirmed that this cannot be due to a lack of knowledge concerning the spatial positions of objects in the scene. Hence, rather than a stimulus-driven effect, Zelinsky et al. (1997) observed an effect caused by goal-related mechanisms that presumably drove the eyes in between objects for an optimal gain of knowledge about the object identities.

In conclusion, the relatively simple set of assumptions of the proposed model offer a relatively simple framework to account for a large variety of empirical observations. Additionally, it offers an explanation for all three known factors that drive overt selection. The current work is a new step towards a better understanding of what drives selection behavior; a new approach to integrate the known factors in a common theoretical framework.